A Study on Variable Control of Sound Vibration Form (SVF) for Media Art Creation

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***Abstract*—Media arts created utilizing sound vibration have big visual impact to audiences. One of the well-known artworks created by one of the authors, Naoko Tosa, is "Sound of Ikebana," which combined physical phenomenon, sound shape computing and traditional Japanese flower arrangement culture. The method she used to create the artwork is Sound Vibration Form (SVF), which uses sound vibration as energy source to let pigment or other materials jump up from speaker, and be shot by a high-speed camera of 2000 frame/sec.**

In order to create appropriate shapes using SVF, we need to control key parameters such as sound frequency, shape of sound, paint quantity, paint viscosity, type of materials, etc. We have carried out various experiments of SVF by changing these parameters and have analyzed how the changes of these parameters create various shapes. We believe that SVF could support artists to create high-quality artworks and therefore would become an art creation support tool.

Keywords—sound image; high-speed camera; media art; culture; sound vibration form

I. INTRODUCTION

New technologies can change the ways of communication, and also influence the field of art. This is why methods of creating artworks are always keeping the pace with time. From Buddha sculpture in Nara, Japan to modern movies of Hollywood, they are all using cutting-edge technologies of the era. [] Artists or scientists can use technologies to deliver more complicated information to audiences, especially in this ICT era, in which information explodes rapidly. On the other hand, what we want to deliver could be easily submerged by information flow from everywhere. Therefore, we need something not only new but also eye-catching to deliver our messages effectively. One idea is to deliver our messages in the form of artworks with rare visual impact created using latest technology.

We are studying ways to create media arts by capturing beauty in super slow motions of physical phenomena. One of the methods we found is Sound Vibration Form (SVF), which transforms sound vibration into visible motion videos. This has been achieved by observing super slow motion of physical phenomenon using a high-speed camera. We put various materials like pigments with controlled viscosity on a speaker, and paly a sound. Then the vibration generated by sound gives energy to the pigment and eject it into air. The speed of the phenomenon is very fast, so we uses high-speed camera to capture it. A 2000 frame per second high-speed camera can expand 1-second real time motion to 66 seconds. This can help us to observe super fast material motions and to visualize them. Careful combination of colors and materials can make artworks created from SVF visually impactful and meaningful.

With the help of SVF, Naoko Tosa and our team could create lots of artworks. These artworks include "Tosa Rimpa Series," "Sound of Ikebana," "Genesis," etc. These artworks combined science and Japanese culture, attracted audiences from all over the world, and realized communication with people whose background is far away from Japanese culture.

However, SVF based on physical phenomenon is difficult to be controlled. There are too many influential factors, which makes it difficult for us to fully control the result.

In order to create artworks that fully express artist's idea, we need to control the art creation process somehow. To realize this, we have carried out several experiments of controlling variables to find out influential parameters. The experiments include changes of parameters such as paint quantity, paint viscosity, sound frequency, material type and sound wave shape. If these parameters can be controlled relevantly in the art creation process, it would shorten the creation process and created arts based on SVF would express artist's inner thought well.

Simple intro of structure.

In chapter 2, we will introduce the artwork, Sound of Ikebana, created by Naoko Tosa, utilizing SVF method, and how this artwork have been accepted by the world. In chapter 3, we will introduce the details of SVF method. In chapter 4, we will introduce the experiments and analysis. Then chapter 5 concludes the paper.

II. Sound of Ikebana

Sound of Ikebana is an artwork that was created from the sound vibration form (SVF) by Naoko Tosa in 2013 [9]. In this artwork, sound was used as an energy source, which can eject color paint up above the speaker. Then a high-speed camera was used to capture the motion of the paints. By expanding the time of the phenomena to about sixty times, we can see the beautiful shape of the paint, which looks like "Ikeban," the traditional Japanese flower arrangement. This artwork is a combination of latest technology and the traditional Japanese flower arrangement culture. This is also the first artwork achieved utilizing SVF. We carried out projection mapping to exhibit the artwork to many people in different countries and areas, and gained attention of millions of people. The artwork has won the prize of Good Design Award of 2014 [10].

Sound of Ikebana consists of four short video, each of which represents one of four seasons in Japan. It uses specific colors to represent flowers in a certain season (Fig. 1). By utilizing various types of color paints and liquid, the artist tried to express Japanese flowers in seasons, such as palm and cherry in spring, cool water and morning glory in summer, red leaves in autumn, and snow and camellia in winter. Also the artist tried to express various color variations such as prayerful colors of Buddhism, Japanese "Wabi-sabi" colors, colors of delicious food, cute colors of "Cool Japan," gorgeous colors featuring Christmas and New Year season, etc [11]. To let foreigners easier to easily understand Japanese culture and four seasons, some Japanese traditional Haikus are also overlapped on the artwork (Fig. 2).

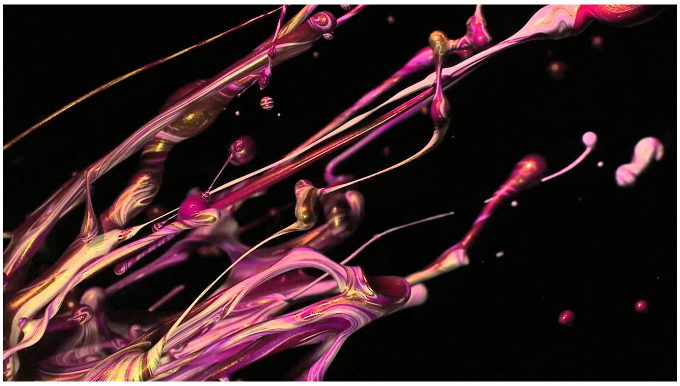


Fig. 1. Glimpse of Sound of Ikebana, Created by Naoko Tosa, 2013 ([12])

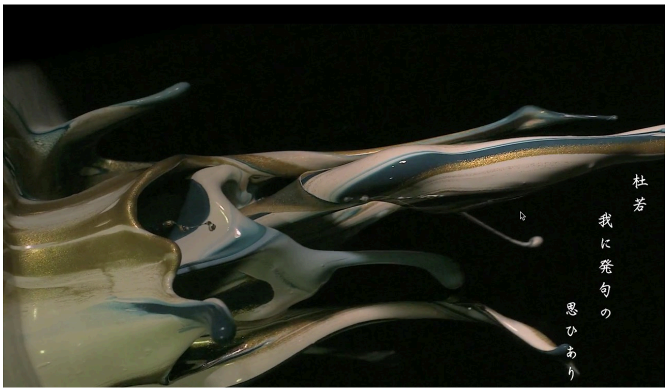


Fig. 2. Sound of Ikebana with Haiku. Naoko Tosa, 2013 [13].

By watching these series of video artworks audience would have a feeling of wonder generated by organic and mysterious figures of the liquid and also its unforeseeable movements. At the same time audience would feel the connection of long history and traditional cultures in Asia, which is really meant by the artist.

To display the artwork to many audience in an effective way, a projection mapping have been usually used. We have carried out projection mapping exhibit Sound of Ikebanb was Singapore ArtScience Museum [14]. The moving images of Sound of Ikebana was projected on the wall of the lotus like ArtScience Museum. The artwork became a part of the city night view, and the whole city was able to appreciate it (Fig. 3). This projection mapping has won the prize of the Good Design Award, 2014. Sound of Ikebana can be regarded as a pioneering trial of intercultural communication based on media art, which was greatly succeeded.

Fig. 3 Sound of Ikebana projection mapping at ArtScience Museum, Singapore, 2013

III. Sound Vibration Form

The sound vibration form (SVF) is a new art creation method, which generates various changing shapes of materials ejected up by sound vibration [28]. The vibration of the sound and generated material movements are so fast and we cannot see the phenomenon with human nekid eyes. Therefore, we use a high-speed camera to record the phenomenon and replay it at a speed acceptably by human eyes. In the production of Sound of Ikebana, we used the rate of 2,000 frames per second, and replayed it with 30 frames per second. This means we expanded real time to 67 times (1 second expanded to 67 seconds). Then beautiful phenomenon that are hidden in nature is able to appeal to us directly.

To create Sound Vibration Form, we upgrade the system studied by Chen et al. in 2016 [29]. We put a rubber sheet on a bass speaker; pull the rubber to stretch it. Then we put mixture of various color paints and other materials that were carefully predesigned on the fixed rubber. Then, once the controlled sound comes out from the speaker, the vibration from the speaker gives energy to the color paints and materials on the rubber, and ejects the materials up. Then we use the high-speed camera to capture the motion.

Equipment and Setting

In order to change sound into visible shape, we used the following equipments.

☐ **Bass speaker x 1** (FOSTEX PM-SUBn, 20cm Cone, 8 Ω, 68W, 150Hz max).

☐ **Rubber sheet x 1** (250mmx250mmx0.5 mm).

☐ **High-speed camera x 1** (Nac HX-3 4K 2000 frames per second).

☐ **Computer x 2** (Each for speaker control and high-speed camera control).

☐ **Illumination 300W xenon light x 2**.

☐ **Black background fabric x 1**.

☐ **Materials for experiment** (viscosity controlled poster paint, jelly, foam, etc.)

The flowchart illustrated in Fig. 4 explains the creation process. First, we put a rubber sheet on the top of the bass speaker, and stretch the rubber to make it have enough tension. Then we fix the rubber to make it stable. After this, we put various materials, whose quantity and viscosity are carefully controlled, on the rubber. A rap top computer is used to generate sound whose shape and frequency are controlled, and the generated sound is fed to the speaker to play it. The vibration of the sound then is delivered to the rubber and to the materials on it. The materials are forced to jump from the rubber rapidly. A high-speed camera is to shoot the changing shape and another computer connected to the camera records this. Because the actual shapes of the materials are only around 5 cm tall, we need to locate the camera close enough to the speaker to obtain better graphic quality. This can make the depth of the field shallow, and the motion of the materials can easily goes out of range. To solve this problem, we adjust the aperture to the smallest size. Also to realize a bright for better quality of the shot video, we introduced two 300W xenon lamp. This could maintain a wider depth of field. The top-down view of the system is illustrated in Fig. 5.

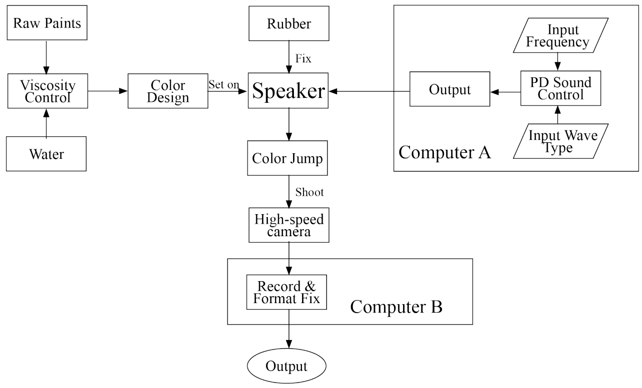


Fig. 4. The flowchart of sound vibration form production

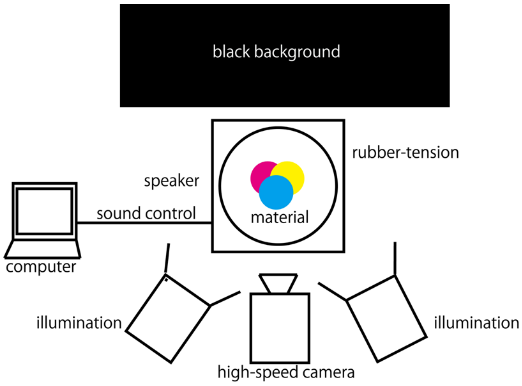


Fig. 5. Top-down view of the Sound Vibration Form system.

Sound Controlling Program

One of the key parameters is the sound wave frequency. For the sound frequency control, we used the sound control software called Pure Data (PD) (https://puredata.info/) ([30]). PD is an open-source visual programming language, which is concentrated on media programming, especially on music area or multimedia.

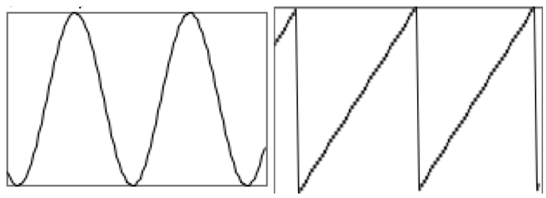


Fig. 6. Shape of sound waves generated by the program. Left: Sine wave generator. Right: Zigzag wave generator.

We created two PD programs to realize accurate sound frequency control. The two figures above show the program we created (Fig. 7). The left is the program to produce sine wave sound, and the right is a program to produce zigzag wave. After typing in relevant number in the box, we can produce the exact frequency sound wave through the programs. The horizontal bar of the program controls the volume of the sound.

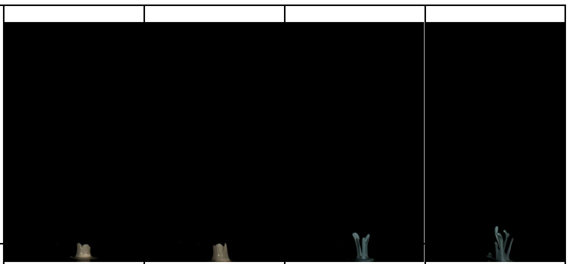
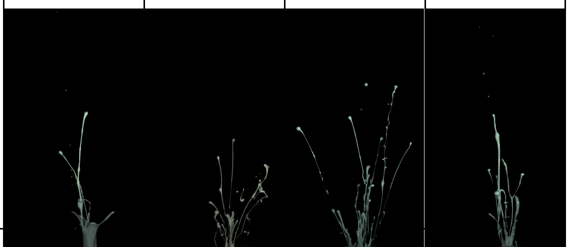
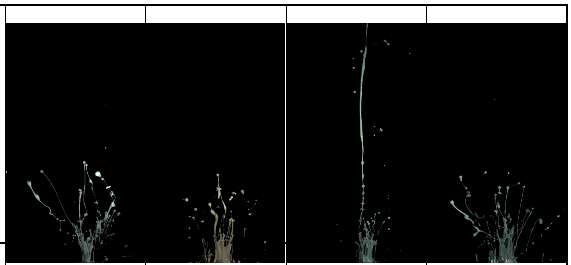
IV. Experiments and Analysis

We carried out various experiments changing key parameters. Below is the brief explanation of the experiments.

Viscosity

Raw paint of white poster color was used here. We mixed the paint with water to control the viscosity. For each experiment, we used 20g of paint and mixed it with water ranging from 0g to 3.75g with the increase of 0.25g for each time. Table 1 shows the result of the experiment.

TABLE I. Influence of Viscosity (Sound frequency was 32 Hz. Sound shape was sine. Quantity was set to 6 g.)

Observed phenomenon				
Weight of water added for 20 g of raw paint	0 g	0.25 g	0.5 g	0.75 g
Observed phenomenon				
Weight of water added for 20 g of raw paint	1 g	1.25 g	1.5 g	1.75 g
Observed phenomenon				
Weight of water added for 20 g of raw paint	2 g	2.25 g	2.5 g	2.75 g
Observed phenomenon				
Weight of water added for 20 g of raw paint	3 g	3.25 g	3.5 g	3.75 g

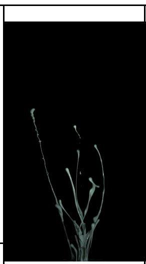
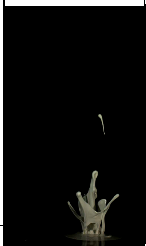
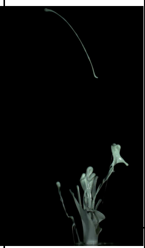
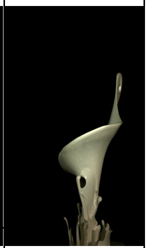
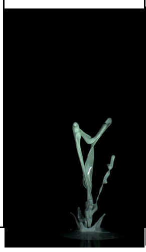
According to the result of the experiments, we found that the paint is too sticky to jump up when water under 1g was added. Beautiful paint shape could not be observed. For added water ranging from 0g to 0.5g, the height of jumping paint is around 3cm. The shape of the paint had no division. For 0.5g to 1g added water, paint could jump up to 5cm. Several branches and layers of the paint form could be observed. For 1g to 2g added water, the characteristic Ikebana-like paint form could be observed clearly. In these cases, paints could jump up to 15cm, and had clearer branches. Mantle-like shape could be generated more frequently in this viscosity range. We consider that this viscosity range is best for artists to create artworks. For above 2g added water, paint jumped higher, paints were divided into a set of paint drops. When 2.5g water added, the paint could jump up to 25cm, with more paint drops generated. At this range, we consider that the viscosity was too low for art creation. Mantle-like shape could not be generated in this viscosity range. For 3g to 3.75g added water, paint could generate more branches and very easy to become droplets. Interesting thing is that the jumping height basically decreased, but occasionally the paint could jump up very high with over 30cm height.

Quantity

We carried out experiment by changing quantity of paint on the speaker every from 2g to 30g with the step of 2g keeping the same viscosity, and observed the generated paint shape. Table II shows the results.

TABLE II. Influence of Quantity (Sound frequency was 32 Hz. Sound shape was sine. Viscosity was set so that the ration of 20 g raw paint mixed with 1.5 g water was kept.)

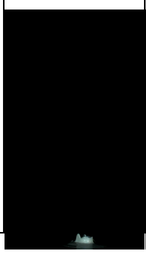
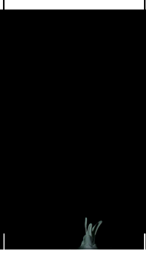
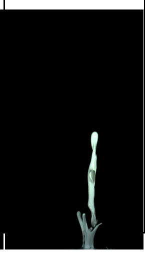
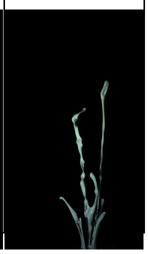
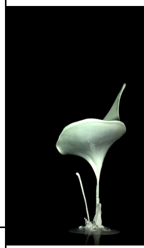
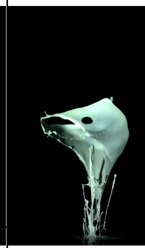
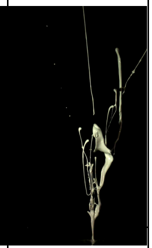
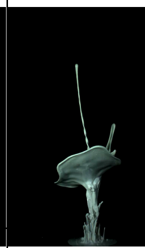
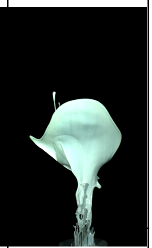
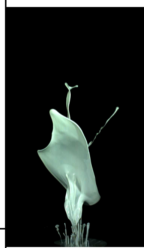
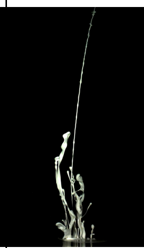
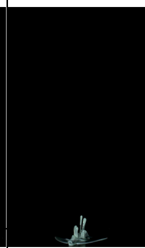
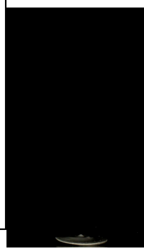
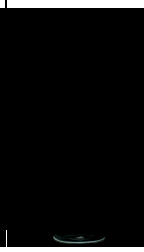
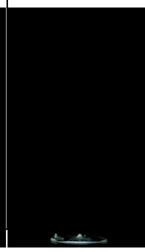
Paint quantity	2 g	4 g	6 g	8 g
Observed phenomenon				
Paint quantity	10 g	12 g	14 g	16 g

Observed Phenomenon				
Paint quantity	18 g	20 g	22 g	24 g
Observed phenomenon				
Paint quantity	26 g	28 g	30 g	
Observed phenomenon				

When only 2g paint was added, the jump of the paint could not be observed clearly. When 4g paint was added, braches of paint could be observed, but not very high. The height was around 7cm to 8cm. When 6g paint was added, the paint height reached 20cm and the characteristic paint form could be observed clearly. For 10g to 14g of added paint, we could observe more paint branches and the shapes were like stream. For 16g added paint, the characteristic mantle shape could be observed more easily. When the quantity reached 20g, mantle shape could be generated more often. For 22g to 30g of added paint, the results were almost similar to the result with 20g.

Frequency of Sound Wave

According to our preliminary experiments, we found that the paint on FOSTEX PM-SUBn speaker started jumping up at 20Hz. So the experiment started from 20Hz. We carried out experiments for each increase of 4Hz starting from 20Hz until 92Hz. The results are shown in Talbe III. As we have changed the speaker, the observed phenomena were somehow different from previous experiments.

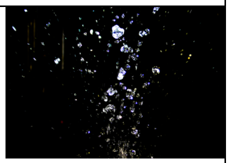
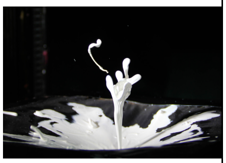
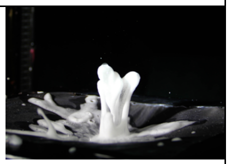
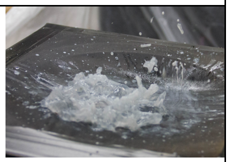
Frequency	20 Hz	24 Hz	28 Hz	32 Hz
Observed phenomenon				
Frequency	36 Hz	40 Hz	44 Hz	48 Hz
Observed phenomenon				
Frequency	52 Hz	56 Hz	60 Hz	64 Hz
Observed phenomenon				
Frequency	68 Hz	72 Hz	76 Hz	80 Hz
Observed phenomenon				
Frequency	84 Hz	88 Hz	92 Hz	
Observed phenomenon				

The paint started to jump at 20Hz. First, the jump up height was low. But for higher frequency, the jumping up height increased rapidly. When the frequency reached 24Hz, the paint could reach 5cm height. And when it reached 28Hz, the paint reached 15cm height. At the frequency 32 Hz, paint jumped higher with more branches. The height reached 20cm. For 36Hz to 44Hz, we could observe that the mantle-like shapes were generated. For 48Hz to 52Hz, the frequency became too high to create the mantle shape. Paint jumped higher than the case of 30cm. For 56Hz to 68Hz, the mantle-like shape appeared again, but there are more branches near the foot of the paint. The height of jumped-up paint decreased to 20 ~ 25cm. At 72 Hz, no mantle shape could be observed anymore. The shape of the paint was like zigzag stream more and more. The height was lower than 15cm. For the higher frequency, jumped up paint dropped rapidly. For 76Hz to 92Hz, paint could jump no more than 5cm.

Materials

We carried out several experiments changing the materials to be jumped up. Table IV shows the results.

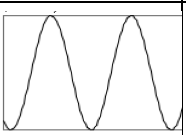
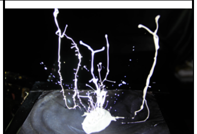
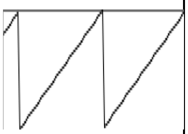
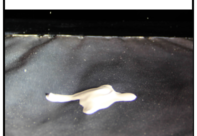
TABLE IV. Influence of Viscosity for Different Materials (Sound frequency was 32 Hz. Sound shape was sine.)

Material	Observed phenomena	
Water	Water jumped up from the center of the rubber-tension and then rapidly change to small sphere shaped drops. And it jumped very high. The highest drop reached over 50cm. The average was 40cm.	
Paints	The height that jumped up paints reached is only half of water's case. And it didn't separate to small drops and maintained an unbroken shape. Finally, it changes to stream shape. The height of the paint was 25cm.	
Foam	Though the shape of foam changed a lot, it didn't separate. The foam only reached the height of 10cm.	
Jelly	Jelly only created big waves on the surface of the rubber, but didn't jump at all.	

Shape of sound wave

Table IV shows the results of the change of the sound wave shape.

TABLE IV. Influence of the Shape of Sound Wave (Paint was set to medium viscosity. Quantity was set to 10 ml. Sound frequency was set to 32 Hz.)

Type of wave		Observed phenomena	
Sine wave		The vibration provided by sine wave could create significant form. The height of the paint reached 30 cm.	
Zigzag wave		The vibration provided by zigzag wave could not even make paint jump. This phenomenon happened no matter which sound frequency we chose.	

V. Conclusion

In this paper, we described a new method called SVF (sound vibration form) that was developed as a tool for media art creation taking the artwork called "Sound of Ikebana" as an example. We carried out various experiments to find out the basic principle of SVF by changing its several key parameters. Although the 5 parameters described in the paper are just a part of all the considerable parameters, we found that, if these 5 parameters are properly controlled, art creating process would become more effective and artists could create artworks that well express their ideas and concepts. By utilizing the results described in this paper, we believe that artists could create artworks more effectively.

As further research we plan to use more types of materials other than pigment, jelly, or foam. For example, materials such as super cooled fluid, which combined more physics, will be used in our coming experiments.

In the present era, where people are surrounded by flood of information, artists need effective way of art creation to attract attention from audiences. We expect that Sound of Ikebana would have chances to be exhibited in many places over the world and would be appreciated by countless audiences thanks to its visual impact, which is achieved with the integration of science and art.

We believe that science and art should be integrated more. Many scientific phenomenon have been underestimated or neglected as sources of art creation, although they have potential to be able to create impactful arts. The integration of science and art in proper way could expand the ways of art creation, and also effective for audiences to understand science.

References

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